NOBLE GAS STUDIES OF MARTIAN METEORITES: DAR AL GANI 476/489, SAYH AL UHAYMIR 005/060, DHOFAR 019, LOS ANGELES 001 AND ZAGAMI J. Park, R. Okazaki and K. Nagao. Laboratory for Earthquake Chemistry, Graduate School of Science, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan (jisun@eqchem.s.u-tokyo.ac.jp)

Introduction

Seven Martian meteorites, Dar al Gani (DaG) 476, Dar al Gani (DaG) 489, Sayh al Uhaymir (SaU) 005, Sayh al Uhaymir (SaU) 060, Dhofar (DHO) 019, Los Angeles (LA) 001 and Zagami, have been studied for noble gas concentrations and isotopic compositions by stepwise heating and total melting method. These meteorites have been classified as basaltic shergottites.

DaG 476 and DaG 489 were found in Libyan Sahara desert (1998 and 1997). SaU 005(1999), SaU 060 (2001) and DHO 019 (2000) were recovered in Oman. LA 001 (1999) was found with LA 002 in the Los Angeles, USA, but the original finding place was somewhere in Mojave desert. Whereas Zagami (1962) fell on Nigeria, six other Martian meteorites were found from hot deserts.

According to [1], DaG 489 has similar characteristics and assumed to be paired with DaG 476. Moreover, SaU 005 shows close resemblance in its chemistry and petrology to DaG 489/476 [2]. The bulk chemistry of DHO 019 is remarkably close to the groundmass of EETA 79001 [3], in spite of its considerably long cosmic-ray exposure age about 20.4 m.y. [4]. Zagami was admitted as the second Martian meteorite containing the significant amount of trapped Martian atmosphere [5]. Even though most of the plagioclase has been changed to maskelynite, Zagami is textually and mineralogically similar to terrestrial diabases except petrological and chemical distinctions [6].

In this work, we report the concentrations and isotopic ratios of noble gases of DaG 489, SaU 005/060, DHO 019, LA 001 and Zagami measured by stepwise heating (SH). Based on ^{81}Kr-Kr ages, the terrestrial ages of DaG 476, SaU 005 and DHO 019 are also calculated. The long terrestrial ages for DHO 019 and DaG 476 show that they have survived from weathering effects at the hot deserts. K-Ar gas retention ages and the cosmic-ray exposure ages were calculated. And the concentrations of ^{80}Kr produced by neutron capture from Br were calculated.

Experimental Method

Seven Martian meteorites were analyzed by using a mass spectrometric system (modified-VG5400/MS-II) at the Laboratory for Earthquake Chemistry, University of Tokyo. They were DaG 489 - 0.1238 g, SaU 005 - 0.1207 g, SaU 060 – 0.0965 g, DHO 019 - 0.1151 g, LA 001 – 0.101 g and Zagami – 0.1999 g. Three Samples DaG 476 – 0.428 g, SaU 005 – 0.255 g, DHO 019 – 0.3180 g were prepared for total melting (TM) experiment to measure radioactive isotope ^{81}Kr. The noble gases were extracted at the six different temperatures of 400, 600, 800, 1000, 1300 and 1750 °C. Then the gases were purified by using Ti, Zr getters. Four fractions of noble gases (He-Ne, Ar, Kr, and Xe) were measured separately: He and Ar were measured by using the Daly-multiplier system, and most of Ne and Kr, Xe by an ion-counting system.

Results and Discussion

The concentration of the cosmogenic nuclides ^{3}He, ^{21}Ne, and ^{38}Ar (10^{-8} cm^{3}STP/g) are (1) DaG 489 $^{\mathbf{SH}}$ [4]– 1.34, 0.258, 0.119, (2) DaG 476 $^{\mathbf{TM}}$ – 1.28, 0.254, 0.0825, (3) SaU 005 $^{\mathbf{SH}}$ [4]– 2.11, 0.235, 0.0789, (4) SaU 005 $^{\mathbf{TM}}$ – 1.61, 0.223, 0.0733, (5) DHO 019 $^{\mathbf{SH}}$ [4]– 18.4, 3.99, 1.65, (6) DHO 019 $^{\mathbf{TM}}$ – 23.9, 5.53, 1.70, (7) LA 001 $^{\mathbf{SH}}$ –2.59, 0.589, 0.382, (8) Zagami $^{\mathbf{SH}}$ – 6.14, 0.797,0.346, respectively. (SH- stepwise heating method, TM- total melting method)

K-Ar ages and cosmic-ray exposure ages of seven martian meteorites are given in Table 1. There have been similarities between DaG 489, DaG 476, SaU 005 and SaU 060, not only for the Mars ejection age but also for the pattern of the noble gas concentrations during the stepwise heating. Cosmic-ray exposure ages using cosmogenic ^{3}He, ^{21}Ne and ^{38}Ar are about 1~3 m.y., except that of DHO 019. The DHO 019 shergottite has extremely long cosmic-ray exposure age of 20 m.y. approximately. In addition, because Martian meteorites have trapped the Martian atmosphere to some extent with high ^{40}Ar/^{36}Ar ratio, K-Ar age was estimated by using ^{40}Ar concentrations under the temperatures of 1000°C. The obtained ages range between 0.07 and 1.01 b.y., which are typical ones reported for Martian meteorites.

***Table 1*. The cosmic-ray exposure ages and K-Ar ages of Martian meteorites.**

Meteorite	T_3 (Ma)	T_{21} (Ma)	T_{38} (Ma)	K-Ar age (Ga) (≦1000 ºC)
DaG 489 (SH) +	0.80	0.94	1.01	0.97 ± 0.11 K=315 ppm [7]
DaG 476 (TM)	0.77	0.94	0.64	0.81 ± 0.09 K=315 ppm [7]
SaU 005 (SH) +	1.27	0.83	0.87	1.01 ± 0.11 K=183 ppm [8]
SaU 005 (TM)	0.97	0.78	0.81	1.51 ±0.14 K=183 ppm [8]
SaU 060 (SH)	1.27	1.12	0.79	0.50 ± 0.06 K=183 ppm [8]
DHO 019 (SH) +	11.1	17.1	14.5	0.75 ± 0.09 K=498 ppm [9]
DHO 019 (TM)	14.4	23.7	14.9	1.43 ± 0.14 K=498 ppm [9]
LA 001 (SH)	1.58	2.97*	2.50	0.07 ± 0.01 K=1910 ppm [10]
Zagami (SH)	3.70	4.06	2.20	0.56 ± 0.07 K=539 ppm [11]
Zagami (TM)	2.83	4.18	2.03	1.79 ± 0.16 K=539 ppm [11]

+ : recalculated based on the noble gas composition data from Ref [4]
* : Production rate P_{21}=1.98x 10^{-9} ccSTP/g/m.y. in Ref [13] is used.

Based on ^{81}Kr-Kr apparent ages, the terrestrial age of DaG 476, SaU 005 and DHO 019 are also calculated as 0.14, 0 and 0.28 m.y., respectively (Table 2). The long terrestrial ages for DHO 019 and DaG 476 show that they have survived from weathering effects at the hot deserts. The resistivity against the weathering may be due to their metal-less achondrites mineralogy.

***Table 2.* ^{81}Kr-Kr apparent ages (T_{81}), terrestrial ages (T_t) and ejection ages (T_{ej}) of Martian meteorites.**

	T_{81} (Ma)	T_t (Ma)	T_{ej} (Ma)#
DaG 476	1.5	0.14	1.08
SaU 005	-	-	0.81
DHO 019	51.5	0.28	20.7
LA 001	3.10*	-	2.97
Zagami	2.98$	0.00	4.12

\# : Cosmic-ray exposure ages, T_{21} in Table 1 are adopted.
* : Terribilini et al. (2000) – Ref [12],
$: Eugster et al. (2002) – Ref [13]

The cosmic-ray irradiation, which produces high-energy secondary neutron, is the neutron source of meteorites. Table 3 shows the concentrations of cosmogenic ^{83}Kr and neutron-produced ^{80}Kr from ^{79}Br. The neutron-produced noble gases of seven Martian meteorites were calculated by using the following formula.

$$^{80}Kr_n = {}^{83}Kr_c\{({}^{80}Kr/{}^{83}Kr)_c - ({}^{80}Kr/{}^{83}Kr)_s\} \qquad [13]$$

Cosmogenic Kr is composed of two components, one is produced by neutron capture on Br and another by spallation reaction neutron-capture (n) and spallation (s). We assumed that $({}^{80}Kr/{}^{83}Kr)_s$ is 0.495 [14]. Excesses of $^{80}Kr_n$ and $^{82}Kr_n$ from Br are clearly visible for LA 001, DHO 019 and Zagami (Fig. 1), while DaG 489/476 and SaU 005/060 show no clear difference from Martian atmosphere adopted by Eugster et al.[13].

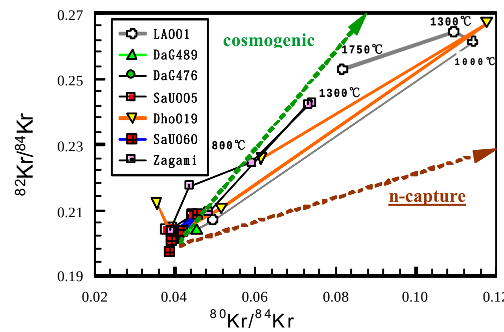

***Figure 1.* The plot of ^{80}Kr/^{84}Kr versus ^{82}Kr/^{84}Kr in seven Martian meteorites.**

***Table 3.* Isotopic ratios of Kr, cosmogenic ^{83}Kr and neutron-produced ^{80}Kr concentrations of Martian meteorites.**

	$^{83}Kr_c$	$^{80}Kr_n$	$^{80}Kr_n$ [13]
	10^{-12} cm^3STP/g		
LA 001 (SH)	2.75	1.42	0.93
DHO 019 (SH)	4.09	1.97	-
DHO 019 (TM)	2.66	3.31	
Zagami (SH)	1.52	0.36	0.22
Zagami (TM)	0.83	1.03	
DaG 489 (SH)	-	0.24	-
DaG 476 (TM)	-	0.62	
SaU 005 (SH)	-	0.21	0.12
SaU 005 (TM)	-	0.23	
SaU 060 (SH)	-	0.20	

(SH: Stepwise Heating method, TM: Total Melting method)

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